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MECHANICAL DRAFTING AND DESIGN TECHNOLOGY, JOB DESCRIPTIONS AND SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS.

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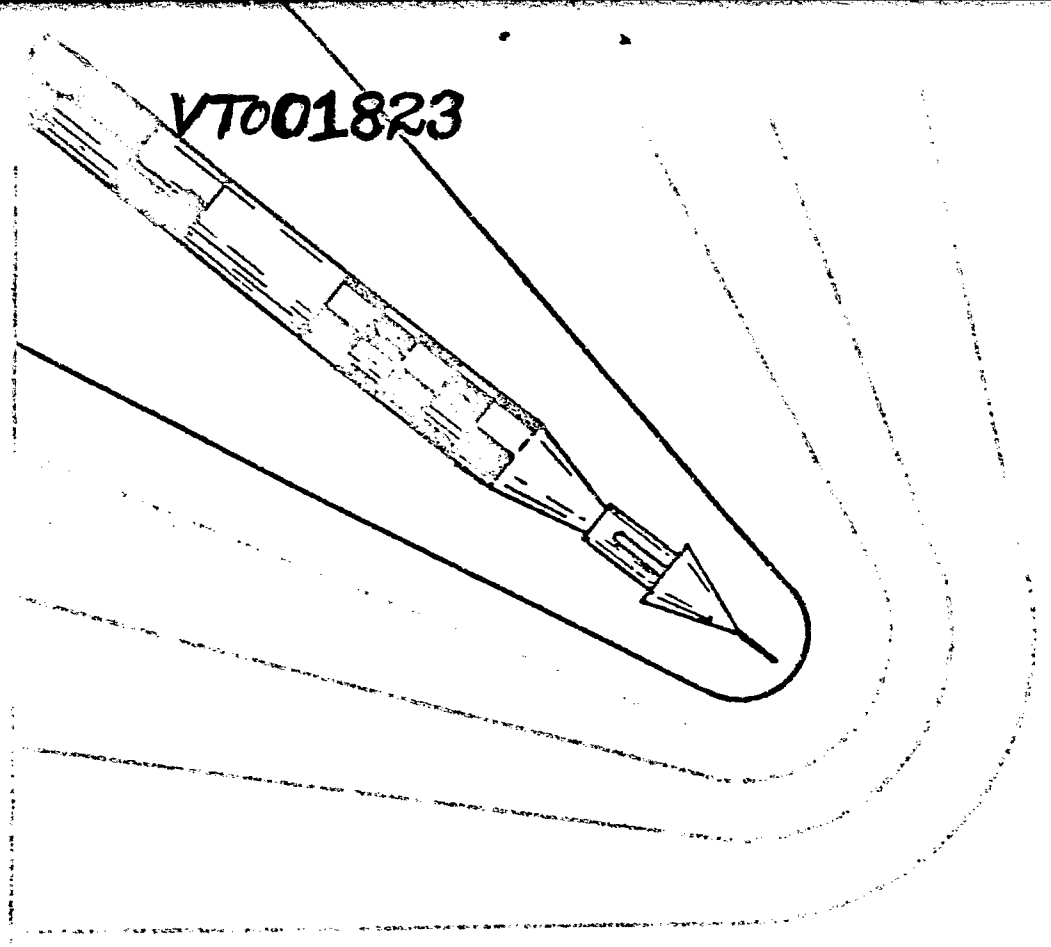
THIS IS THE FIRST OF A SERIES DESIGNED TO PROVIDE AID TO STATES IN ORGANIZING AND OPERATING PROGRAMS UNDER TITLE VIII OF THE NATIONAL DEFENSE EDUCATION ACT, PUBLIC LAW 85-864. IT FURNISHES--(1) GENERAL INFORMATION ABOUT A TECHNOLOGY OR BROAD FIELD OF WORK, (2) COMPOSITE JOB DESCRIPTIONS OF REPRESENTATIVE OCCUPATIONS IN THAT FIELD OF WORK, (3) A METHOD FOR DETERMINING THE RELATIONSHIP BETWEEN JOBS IN ORDER TO ESTABLISH A CLUSTER OR GROUP OF RELATED JOBS, AND (4) A METHOD FOR DETERMINING THE COURSES OF STUDY REQUIRED TO PREPARE STUDENTS FOR A CLUSTER OR GROUP OF CLOSELY RELATED OCCUPATIONS, OR A SPECIFIC OCCUPATION WITHIN A GROUP. THE CHAPTERS INCLUDE--THE FIELD OF WORK, JOB RELATIONSHIPS, JOB DESCRIPTIONS, AND TRAINING REQUIREMENTS. THIS DOCUMENT IS ALSO AVAILABLE AS FS 5.280--80000 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, FOR $0.25. (EM)



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JOB DESCRIPTIONS AND SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS.

Mechanical Drafting and Design Technology.

I. The Field of Work

II. Job Relationships

III. Job Descriptions

IV. Training Requirements

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE . . . . . Arthur S. Flemming, Secretary

OFFICE OF EDUCATION, Washington, D.C. . . . . Lawrence G. Derthick, Commissioner

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FOREWORD

Knowledge of jobs is fundamental to the planning of any occupational training program. Effective surveys aimed at determining the employment opportunities for highly skilled technicians in the labor market area served by the schools require some general understanding of the titles and duties of jobs and the training required for job performance.

This publication, covering mechanical drafting and design technology, is the first in a series of miscellanies designed to provide information to help the States organize and operate programs under title VIII of the National Defense Education Act, P. L. 85-864. They will indicate how the States can use composite job descriptions and job relationship techniques to facilitate the planning of training programs. Each publication will contain the following information and suggestions:

1. General information about a technology or broad field of work.
2. Composite job descriptions of representative occupations in a field of work.
3. A method for determining the relationships between jobs in order to establish a cluster or group of related jobs.

4. A method for determining the courses of study required to prepare students for a cluster or group of closely related occupations, or for a specific occupation within a group.

The individual job descriptions are illustrations of drafting and design occupations and are not meant to be all-inclusive. They are based upon source data resulting from occupational analysis studies made in a number of employer establishments in different parts of the nation. Therefore, they must be considered as composites which will not match exactly any single position in a specific establishment.

It should be recognized that these job descriptions represent typical areas of activity in which technicians are engaged and should not be considered in all cases as entry jobs. Technicians who have received instruction in an organized training program for a specific technology are provided with the skills and knowledges of this work field, but, like the young medical doctor or graduate engineer, they serve a period of internship in order to learn how to apply their knowledge to technical problems likely to be encountered in the specific job to which they are assigned.

A graduate of a technical course in mechanical drafting and design technology may be hired to work in tool engineering. Usually, he will start as a Detailer to become familiar with the conventions,

techniques, terminology, and other factors peculiar to the industry and to the specific work assignment. He may soon advance to Draftsman, and later be assigned to design simple tools. Eventually, he is capable of performing successfully as a Tool Designer.

This manuscript was prepared by Clarence E. Peterson, Occupational Analyst, Area Vocational Education Branch, with the assistance of other members of the staff of that Branch.

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INTRODUCTION

Accurate information about jobs is needed for many programs involved in the recruitment, employment, placement, training, and utilization of manpower. The nature of the job information required varies in type and approach according to the program contemplated. Regardless of its ultimate use, however, the data must be accurate, detailed, and presented in usable form.

Job analysis is the process of obtaining and reporting pertinent information relating to the nature of a specific job. It is the determination of those actions, skills, knowledges, abilities, and responsibilities which are required of the worker for successful job performance and which differentiates the job under study from all others.

Basically, there are three parts to the analysis of any job: (1) the job must be completely and accurately identified; (2) the tasks or job elements which describe the duties and worker actions required in performing the job must be complete and accurate; and (3) the knowledge and skills which are required for each job element must be specified.

There are several methods of making a job analysis. Probably the most widely used are those described in the "Training and Reference Manual for Job Analysis," prepared by the U. S. Department of Labor (see Addenda).

It is assumed that experienced personnel will be assigned to make the necessary job analyses to provide the basic data which can be translated into curriculums designed to prepare workers for a specific field of work. Therefore, it is not the purpose of this document to describe the methods and techniques for analyzing jobs. Rather, its purpose is to explain how the basic occupational information resulting from a job analysis study is used to determine the relationship between jobs and the skills and abilities required for successful job performance. Such information can be used to establish the courses of study required to prepare students for a cluster of closely related jobs or for a specific occupation within a group.

Because of the specialized nature of highly skilled technician jobs, it is essential that the data be as detailed and complete as

possible. This is especially true of educational and training requirements where the skills and knowledges required for employment in these occupations should be clearly defined, for example: (1) basic knowledge of physics concerned with light sources, lenses, and optical instruments is more specific and meaningful than basic knowledge of physics; and (2) must have sufficient knowledge of English grammar and composition to be able to write clear, concise, technical reports is more informative than is required to write moderately well.

Most of the information about technician jobs must be obtained through interviews, with little opportunity for observing the job. Some of these jobs are in classified areas or the end product being worked upon may be classified. In such cases, it may be necessary to interview the technician in a nonclassified area under whatever security regulations may be in effect in the establishment where the study is being made.

A successful training program requires detailed information concerning the nature, duties, responsibilities, job elements, educational requirements, and related factors of each job for which training is contemplated. The content of the training curriculum, and the selection of trainees depend upon a thorough analysis of each job.

SECTION I

THE FIELD OF WORK

Technicians trained in mechanical drafting and design technology are employed in many industries considered necessary to national defense, such as ordnance production and maintenance; power plant equipment production; steel and nonferrous metals production; ship building; aircraft and missile production; electrical and electronics appliances and devices, including computers and testing equipment; nuclear reactors; ventilating, heating, and air conditioning equipment; radio, television, sound recording, and reproduction equipment; and industrial machinery.

The following are typical of the activities in which these technicians are engaged:

a. Developing the design of a section of a major component, secondary element of a major functional system, or a complete minor functional system such as for machinery or aircraft, a missile, or electrical or electronic testing equipment and the like. They usually work from engineering design sketches, notes, design directives, and preliminary data. They often handle all aspects of design in a specialized field and may work as tool, gage, or die designers; machine designers; mechanical draftsmen; engineering drawing checkers; and in related occupations.

b. Investigating pertinent design factors such as ease of manufacture, availability of materials and equipment, interchangeability, replaceability, strength-weight efficiency, customer and contractual requirements, and cost and design trends.

c. Designing components in the development of major design projects for such complicated units as aircraft landing gear, propellers, servomechanisms, mechanical amplifiers, brakes, gear trains, and variable speed changers, which are based on original design concepts or specific engineering ideas.

d. Developing drawings indicating all pertinent fits and tolerances in sufficient detail to make designs understandable, to make test or trial units, or to make production drawings.

e. Drawing preliminary freehand sketches and rough layouts of a proposed design to resolve a project problem. This includes preparation of rough assembly drawings to prove the interrelationship of details and parts including dimensions for all parts and approximate tolerances, and making calculations concerning size, shape or form of parts, simple bearing loads, stresses, strains, speeds, gear ratios, bending moments, fatigue factors, inertia, momentum, centrifugal force, leverages, and other specifications subject to review by project engineer.

f. Designing full-size "packaging" layouts of mechanical hydraulic units and linkages as they will be installed in such limited space as that provided in automatic computers and missiles. This includes indicating the arrangements of the assemblies for installation purposes and the clearances required to avoid interference or contact of the mechanical-hydraulic systems with surrounding mechanisms during operation of the equipment.

Listed below are typical occupations in defense industries where graduates of technical courses are employed:

AIRCRAFT AND MISSILE MANUFACTURING

Engineering Drawings Checker
Loftsman
Design Draftsman, Hydraulic Linkage
Design Draftsman, Electromechanical
Tool Designer
Tool Proofer
Analyst - Gage Design and Planning

ENGINE AND TURBINES

Design Draftsman, Ram Jet Engine
Design Draftsman, Rocket Engine

Engine Development Technician (Internal Combustion)
Steam Turbine Design Technician

MACHINERY AND MACHINE TOOLS

Design Draftsman, Machinery
Layout Man and Checker
Design Checker
Die Designer

SECTION II

JOB RELATIONSHIPS

Before technical curriculums can be established, the individual occupations for which training is needed should be identified. The next step is to analyze each of these jobs and to prepare brief job descriptions covering the work activities, functions, and performance requirements for each occupation.

The occupations should then be arranged in homogeneous groups or clusters, and the kind and amount of basic and applied science, mathematics, etc., required to prepare workers to perform the duties of the job included in each grouping should be specified.

The procedure used in determining the similarities in jobs and the common worker knowledges and abilities involved is called the job relationship technique. The criteria used by industry for establishing job relationships vary. However, jobs usually contain all or most of the following factors which are used in establishing the homogeneous groups or job clusters referred to in this bulletin:

a. The similarity of work performed.

b. The abilities and knowledges required of the worker for successful job performance.

c. The pattern of worker characteristics required by the job, such as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment.

d. The tools, machines, instruments or other equipment used on the job. Also the reading and interpreting of blueprints, or the use of special measuring devices which may be involved.

e. The basic material worked on or with. Occupations may involve working with more than one material, or working with the same material in different forms.

Not all of these factors are matched exactly nor found to be the same for all jobs being considered. However, most of the factors should be present in a cluster of related jobs. For example, in developing the relationships of jobs found in the broad field of drafting and design, it is readily apparent, when using the criteria shown above, that the electrical draftsman and the mechanical draftsman have only one factor in common--that of drawing. The abilities and knowledges required for successful job performance and the basic materials worked upon or with are totally dissimilar. The mechanical draftsman prepares drawings for mechanical devices. He must know how to calculate such engineering details as angles, stresses, strains, strength-weight ratios, and how metals react under extreme temperature changes. He must be familiar with the working properties of metals, metal alloys, and other materials, as well as with machine shop operations and practices. On the other hand, the electrical draftsman prepares plans and wiring diagrams. His knowledges must encompass electricity and magnetism, circuitry, and other factors related to electrical engineering. Therefore, it is evident that these two jobs are not closely related and do not belong in the same cluster or major grouping.

The following example illustrates a procedure for comparing a number of drafting and design jobs in order to arrive at a cluster of related jobs. The job of Tool Designer was selected as a key job and a comparison was made of the characteristics of other drafting and design occupations to show the interrelationship. The characteristics or elements of all of the jobs being considered were identified by means of job analysis. Form "A" provides a graphic illustration of the relationships between the various jobs. A close look at Form "A" discloses that all of the elements are present in the key job (Tool Designer) and most of them are present in the other related jobs. It will be noted that only five of the eight elements are present in the job of Engineering Checker. Usually, if less than half of the elements are present in a particular job, the relationship would not be close enough to warrant its inclusion in the cluster or major grouping.

The job relationship technique can also be used in selecting workers who can become qualified to handle closely related technician jobs in a comparatively short time. It provides a method for making maximum use of available skills. For example, tool makers can perform the functions of tool making and tool designing with a minimum of additional training. In most cases it will not be necessary for them to learn to prepare detailed drawings. They will sketch

Form A. - JOB RELATIONSHIPS

	Ability to develop and design complicated units for mechanical devices	Ability to develop production drawings indicating fits and tolerances in sufficient detail to make designs understandable	Ability to use mathematical principles in computing dimensions, stresses, fatigue factors, etc.	Ability to understand and use standard engineering handbooks and formulas	Ability to understand and interpret intricate engineering drawings	Possesses knowledge of working properties of metals and metal alloys	Possesses skill in the use of precision measuring instruments	Ability to solve fabricating, inspecting and assembly problems	
KEY JOB:									
Tool Designer	X	X	X	X	X	X	X	X	
RELATED JOBS:									
Tool Proofer		X		X	X	X	X	X	
Analyst, Gage Design & Planning		X		X	X		X	X	
Engineering Drawings Checker		X	X	X	X			X	
Loftsman	X	X	X		X			X	
Design Draftsman, Electromechanical	X	X	X	X	X	X		X	
Design Draftsman, Hydraulic Linkage		X	X	X	X	X		X	
Design Draftsman, Ram Jet Engine	X	X	X	X	X	X		X	
Design Draftsman, Rocket Engine	X	X	X	X	X	X		X	
Steam Turbine Design Technician	X	X	X	X	X	X			
Engine Development Technician (int.comb.)		X	X	X	X		X	X	
Design Draftsman, Machinery	X	X	X	X	X	X		X	
Layout Man and Checker		X		X	X	X		X	
Design Checker		X	X	X	X		X	X	
Die Designer	X	X	X	X	X	X	X	X	

the tool to be made and actually construct the finished product, using their tool making experience combined with the new design skills acquired through a relatively short, intensive course of training.

SECTION III

JOB DESCRIPTIONS

The job descriptions included in this section are based on source data assembled from various parts of the country. Since they reflect the occupational situation as it exists in a variety of plants and localities, they must be considered as composites and may not coincide exactly with any single position in a specific employing establishment. However, these descriptions can be readily adapted to fit individual organizational patterns and needs.

Each job description identifies and describes the principle elements of the job and the training and experience required for successful job performance. The job duties and performance requirements for closely related occupations vary from plant to plant and from one industry to another. However, these job descriptions should be useful in identifying technician jobs in the field of mechanical drafting and design. Also they can be used for comparison purposes, which may eliminate the need for time-consuming job analyses of certain occupations. In many cases, the plant job may reveal only minor differences from those shown in one of these job descriptions. In this event, only the differences in job content need be considered. Even in the case of major differences, many of the technician jobs for which training is required will undoubtedly fit into the general framework of the job description.

ENGINEERING DRAWINGS CHECKER

Visually examines airplane or missile engineering drawings to correct errors in computing and recording dimensions and specifications. Compares figures on layout of parts and assemblies with those of drawings, examining angles, tolerances, bend allowances, and dimensions for accuracy. Determines suitability of design, materials, and tooling and fabrication steps, guided by knowledge of drafting and shop methods. Suggests necessary modifications required to correct errors in computing and makes recommendations to reduce scrap and rejections. May draft designs of highly complicated structures, installations, and assemblies to alleviate workload.

Job requires ability to apply principles of mechanics, structures, and design in checking drawings; ability to use descriptive geometry and trigonometry for making necessary calculations; ability to apply a practical knowledge of shop operations and processes. Worker must understand intricate engineering drawings and be able to interpret them. Usually two years of technical training and two years of drafting and shop experience are required.

LOFTSMAN

Lays out to scale on plywood or sheet metal the contours and lines of an airplane and its components preparatory to the making of blueprints. Makes preliminary layouts in reduced scale of exterior surface contours from engineering data and sketches, using such drafting tools as straightedges, triangles, and calipers and employing his knowledge of descriptive geometry and trigonometry and his familiarity with airplane design. Lays out full-scale drawings of airplane structural units, such as fuselages and wings, working from engineering drawings and loftings in reduced size. Transfers the master lines layout and other drawings to detail assembly templates and prepares tables of full-scale offsets of lofted airplane structures for shop use. Coordinates information and corrects errors found in engineering prints for matching assemblies.

Job requires considerable mental application for long periods in preparing layouts. Worker must be able to understand and interpret engineering drawings and sketches; must understand descriptive geometry and trigonometry as they apply to the work; must understand geometry of the airplane; and must have a general knowledge of airplane construction and of shop operations and practices.

DESIGN DRAFTSMAN, HYDRAULIC LINKAGE

Prepares full-size and scale drawings of proposed designs for components of mechanical hydraulic linkage system of guided missiles, following rough sketches provided by the engineer and applying knowledge of drafting and hydraulics to the particular purpose of the system. Determines the form or arrangements of components to be made and the methods and feasibility of production, considering the materials to be used, the weight-strength ratio required, reliability

of parts, and the availability or ease of manufacture, utilizing calculators, slide rules, and knowledge of mathematics coupled with practical knowledge of machine shop practices to compute angles, dimensions, fits, thickness of housing walls, tolerances, and gear teeth data, Draws full-size "packaging" layout and linkage of mechanical-hydraulic components as they will be installed in the limited space in the missile. May conduct laboratory tests of the manufactured components to ascertain action of mechanical linkage and structural soundness of the part, using testing and measuring devices.

This job usually requires about two years of training beyond high school with courses in algebra, geometry (plane, solid, descriptive and analytic), trigonometry, slide rule usage, mechanical drafting, hydraulics, physical metallurgy, physics and machine shop practices. Six months to a year of experience is usually required for graduates of such courses to perform job duties satisfactorily.

DESIGN DRAFTSMAN, ELECTROMECHANICAL

Designs and develops mechanical or electromechanical control units for aircraft and guided missiles to meet performance specifications provided by the customer, studying blueprints of existing control units to determine whether to design an entirely new unit or to modify an existing one. Determines dimensions and shapes of special parts required and materials to be used in their construction, taking into consideration strength and weight of materials, reliability of parts, ease of manufacture, and functional performance characteristics. Consults with shop mechanics to discuss difficulties encountered in machining or assembling the first model in order to determine cause of problems. Modifies sketches or suggests changes in design to overcome machining or assembly difficulties. Draws final sketches, incorporating all design changes that have arisen during the building of the prototype, which are used by a draftsman of lower grade in preparing drawings and specifications for production purposes.

Although some companies require graduate engineers for this job, others find that graduates of schools offering technical institute type training in mechanical drafting and design technology can be productive on simple assignments almost immediately. The course of training should include algebra, geometry, trigonometry, slide rule usage, fundamental physics, basic electricity, metallurgy, machine

and tool design, mechanical drafting, and laboratory work in electricity, and machine shop practices. It usually requires three years of experience for a technician to work alone on major assignments where he designs a complete control system which is driven mechanically or in which electrical impulses actuate the mechanical elements.

TOOL DESIGNER

Develops and designs tools used in forming, bending, milling, reaming, cutting, grinding, and other machining operations required to fabricate metal parts for aircraft and missiles. Works from rough sketches or models of the parts to be produced and determines the type, shape, dimensions, fit, and tolerances of the required tool. Considers the characteristics and properties of the metal to be used in its construction. Prepares detailed drawings and specifications to be used by the Tool Maker, using knowledge of algebra, geometry, and trigonometry in making the required calculations and knowledge of machine shop practices, and strength of materials used in the manufacture of tools. Works closely with shop personnel to explain the working of tools designed and to discuss any problems that may arise in the use of the tools. May direct the work of a small group of draftsmen and may instruct shop mechanics in the making of the tools.

Workers on this job must be familiar with shop equipment; must be familiar with machine terminology and strength of materials used in the manufacture of tools; and must be able to determine the tools required to produce the parts economically, to prepare necessary drawings, and to solve fabricating problems. Employers usually require two years of technical training and two years of drafting and design experience.

TOOL PROOFER

Visually examines, and measures with precision instruments the dimensions and contours of new and revised tools, dies, and fixtures used in fabrication and assembly of aircraft or missile parts to determine if they conform with engineering specifications and feasibility standards. Checks results with operation sheets, tool sketches, and blueprints. Directs tryout runs and occasionally instructs operators in use of tooling to produce acceptable fabricated

parts. Recommends tooling changes, if necessary, by sketching suggested design revisions to improve operating effectiveness and to correct malfunctioning of tools. Consults with tool designers, tool planners, tool makers, and others to coordinate changes in tooling.

Workers on this job must be thoroughly familiar with machine shop equipment and practices; must be able to develop the tools required to produce parts economically, and to solve fabricating problems. Employers usually require two years of technical training and at least two years of tool drafting and design experience.

ANALYST-GAGE DESIGN AND PLANNING

Analyzes engineering change notices, shadow sheets, operation sheets, and blueprints of one or more major phases or areas of production to determine number, type, and design of gages, gears, or equipment required for project development and inspection processes. Prepares layout and design modifications to rectify inspection problems and writes operation sheets to cover assigned projects. Plans methods, revises procedures, and writes instructional guides relating to the proper use of gages and other inspection equipment. Compiles data and prepares detailed reports concerning gage and inspection equipment methods and performance.

Workers on this job must be familiar with machine shop operations and processes in order to revise procedures and write instructional guides for use of gages and other inspection equipment. Must understand intricate engineering drawings and be able to interpret them. The job usually requires two years of technical training in drafting and design and two years of tool drafting and shop experience.

DESIGN DRAFTSMAN, RAM JET ENGINE

Prepares sketches and drawings of ram-jet aircraft mechanisms such as fuel injectors, nozzles, and combustion chambers to be used for experimental purposes. Calculates strength-stress ratio, internal and external forces, and other factors to be considered, using knowledge of algebra for computing ratios and for solving required equations. Determines angles, shapes, and dimensions of component parts, employing knowledge of trigonometry and geometry

and using a slide rule. Draws precise diagrams of parts according to engineering specifications, using knowledge of geometry and mechanical drafting practices. Plans and develops engineer's and own ideas for the new design of engine and parts. Evaluates the use of commercial parts to fit the design. Discusses feasibility of design with coworkers, experimental machinists, and design engineer. Uses complex numerical charts, engineering handbooks, and tables to assist in solving technical problems. Makes records and writes reports of work accomplished on design sketches.

Two years of training in mechanical technology is usually required, including such subjects as algebra, trigonometry, plane geometry, mechanical drawing, machine design, strength of materials, physical metallurgy, and thermodynamics. Workers with suitable backgrounds in mechanical design usually serve one year as a junior draftsman before taking over full responsibility on this job.

DESIGN DRAFTSMAN, ROCKET ENGINE

Designs experimental rocket engine from rough drafts and notes provided by physicist or engineer, using knowledge of physics, thermodynamics, hydraulics, and the behavior characteristics of liquid and solid fuels to determine overall dimensions of the engine and component parts required to meet government standards and specifications. Prepares sketches and drawings of component parts such as combustion chamber, exhaust nozzle, ignition systems, control valves, oxidizer, and pressuring systems to be used in prototype, taking into consideration such factors as effects of extreme temperatures on metals, the relationship of required electrical instrumentation to other equipment, and the physical characteristics and properties of materials involved, using slide rule and mathematical calculations to make the determinations. Advises technicians of lower grade or mechanics regarding machining operations and related problems and corrects sketches, if necessary, to overcome machining or fabrication problems encountered. May install developmental rocket engine in mounts of test stands and supervises repeated simulated test runs of engine until proper conditions for actual test run are achieved. Takes test readings and records test data in numerical and narrative forms; analyzes and summarizes information; and interprets and calculates test data to convert them to usable form for presentation to the scientist, using knowledge of physics, algebra,

and trigonometry to convert test data and his ability to prepare accurate and concise reports.

Two years of postsecondary instruction in the following subjects is usually required: Algebra; trigonometry; physics; plane, solid, and analytic geometry; mechanical drawing; machine design; thermodynamics; physical properties of metal; and machine shop practices. Workers with suitable educational background in mechanical technology need two to three years of research experience in rocketry to perform successfully on this job.

ENGINE DEVELOPMENT TECHNICIAN (Internal Combustion)

Modifies experimental models of internal combustion engines to improve performance and to eliminate production problems. Studies engineering drawings and rough sketches of proposed engine and specifications covering size of bore, stroke, piston displacement, type of cylinder head, and recommended revolutions per minute. Develops dimensions and tolerances for all fixed and moving parts and subassemblies to conform with overall external dimensions of the engine. Selects drawings of standard subassemblies and parts having design characteristics similar to those of the proposed engine, and modifies them, if necessary, by correcting size and tolerance dimensions to meet engineering objectives. May remachine standard parts to conform with specifications, using lathes, shapers, grinders, drill presses, and milling machines and working to tolerances of .001 inch. Inspects and measures parts, using micrometers, vernier scales, and gages. Assembles engine, starting usually with crankshaft and adding other subassemblies as they are made, such as connecting rods, pistons, piston rings, valves, tappets, main bearings, cylinder head, and crankcase, using socket wrenches, screwdrivers, files, scrapers, and other mechanic's handtools. Connects such test equipment as dynamometer, potentiometers, and compression, vibration, and vacuum gages to measure such factors as engine load, revolutions per minute, temperature, compression ratio, torque, fuel and oil consumption, and vibration. Computes horsepower rating of engine under various conditions, using instrument readings, slide rule, power formulas, and knowledge of trigonometry. Conducts life test (1,000 hours) on engine to determine durability. Prepares test data sheets for each test and submits them to engineer with recommendations for engine improvement.

This job requires training in the application of mathematics including algebra, geometry, and trigonometry; physics; basic electricity; electrical and mechanical drafting; auto mechanics; and machine shop operations. Six months on-the-job training is required in interpreting and relating the readings of the dynamometer and other measuring instruments to the factors being studied so that computations of horsepower and other ratings will be accurate. Worker usually assists an engineer in the basic development and usually follows directions of the engineer in redesigning and rebuilding experimental engine to improve performance or to correct production problems.

STEAM TURBINE DESIGN TECHNICIAN

Revises standard designs of bucket blades for large steam turbine-wheel vane sections and other rotor components, such as turbine wheels and dovetail notches for attaching bucket vanes, to meet new steam efficiency and increased kilowatt load requirements. Compares steam efficiencies of standard designs with engineer's specifications to determine extent to which a standard shaped bucket can be modified to meet new efficiency requirements. Experiments by revising the standard design, i.e., expanding bucket widths, revising angles, contour radius of curves, and of throat dimensions in order to arrive at a design which will meet new steam specifications within allowable kilowatt load range and maintain standard strength requirements, taking into consideration centrifugal force stresses. Determines limitations of each experimental design and dimensional change by repeating a series of frequency (area and inertia) calculations, using standard mathematical integration process for each design revision tryout. Also uses trigonometry and kilowatt horsepower calculations in making stress determinations. Considers limitations of manufacturing methods by consulting fabrication shop supervisors to assure that design is feasible and economical from a production viewpoint. Designs, develops, and tests new dovetails for holding vane sections to turbine wheels to satisfy increasingly severe operating conditions, such as additional shear and centrifugal stress due to increased kilowatt loads. Observes test and records instrument readings of kilowatt loading and of elongation stresses. Converts test instrument recordings to standard centrifugal force stress and loading terms, using trigonometry.

Job requires training in mechanical technology including thermodynamics, mechanics of rotating machinery, design of machine

elements, and mathematics including trigonometry and use of sine tables. Training for this job is usually acquired through two years of technical institute type training. Three years experience in steam turbine bucket and rotor design and a general knowledge of the company's mechanical drafting practices and procedures are acquired by on-the-job training. Also included are knowledge of machine shop practices, tool designing, and testing procedures. Great care and accuracy are required since there are few checks of results and the consequences of inadequate design or incorrect fits and tolerances or selection of wrong materials used in the construction may be extremely hazardous and costly.

DESIGN DRAFTSMAN, MACHINERY

Develops and designs component parts and attachments for industrial machinery such as rolling, grinding, or pressing machinery; conveyors; cranes; and machine tools; working from rough sketches and notes provided by the engineer. Determines overall dimensions and shapes of the parts and attachments required to conform with engineering specifications, employing knowledge of trigonometry and geometry and using a slide rule. Determines material to be used in constructing the parts or attachments, taking into consideration the physical characteristics and properties of metals and metal alloys. Calculates strength-stress ratio, internal and external forces, and other factors to be considered, applying algebraic equations for making the necessary calculations. Draws precise diagrams of parts and attachments, indicating fits and tolerances in accordance with engineering specifications, and using knowledge of geometry, machine design, and mechanical drafting practices. Investigates practicability of design in relation to limitations of plant manufacturing facilities or cost availability of new equipment. Uses engineering handbooks and tables to assist in solving technical problems.

Two years of postsecondary instruction in the following subjects is usually required: Algebra; trigonometry; plane, solid, analytic, and descriptive geometry; mechanical drawing; machine design; thermodynamics; physical properties of metal; strength of materials; and machine shop practices. Workers with suitable educational background in mechanical technology need about two years of practical experience to perform successfully on this job.

LAYOUT MAN AND CHECKER

Makes layouts and prepares working plans and detailed drawings of proposed machines or machine parts from rough sketches or notes provided by the engineer. Makes final sketch of the proposed drawing, checking dimensions of parts, material to be used, the relationships of one part to another, and the relation of the various component parts to the whole structure, using knowledge of machine design, and strength of materials. Makes any adjustments or changes necessary to overcome machining or fabrication problems, employing knowledge of machine shop and mechanical engineering practices. May examine engineering drawings to correct errors in computing and recording dimensions and specifications, and compares figures on layout of parts and assemblies with those of engineering drawings, examining angles, tolerances, bend allowances, and dimensions for accuracy.

Workers on this job must be familiar with shop equipment and with machine terminology and strength of materials used in the manufacture of machines and parts. They must be able to prepare detailed drawings for manufacturing purposes and to solve fabricating problems. The job usually requires two years of postsecondary education in algebra; trigonometry; physics; plane, solid, and analytic geometry; mechanical drawing; machine design; physical properties of metals; and thermodynamics. Workers with suitable educational backgrounds generally require about two years of practical experience to perform satisfactorily on the job.

DESIGN CHECKER

Examines revised production drawings of tools, dies, jigs, fixtures, and gages to determine accuracy of changes. Computes dimensions shown on drawings to check proper placement of layout and compares figures on layout of parts and assemblies with those of drawings, examining angles, tolerances, bend allowances, and dimensions for accuracy. Ascertains if parts can be fabricated on machines indicated on revised drawings by checking machine blueprints or through knowledge of machine capacities. Suggests necessary modifications required to correct errors in computing and makes recommendations to make design changes which will facilitate production.

Job requires ability to apply principles of mechanics, structures, and design in checking drawing; ability to use descriptive

geometry, and trigonometry in making necessary calculations, and ability to apply practical knowledge of shop operations and processes. Workers must understand intricate engineering drawings and be able to interpret them. Two years of technical training and about two years of drafting and shop experience are usually required.

DIE DESIGNER

Makes drawings of dies necessary to form a complete stamping, forging, or other part. Decides on the number of sets of dies required to change the metal blank into the finished piece, basing his decisions on a blueprint of the finished part and on his knowledge of dies and machines and of their capacities and limitations. Determines the type, shape, dimensions, fits, and tolerances of the required dies, using knowledge of algebra, geometry, and trigonometry in making the required calculations, and familiarity with machine shop practices, and strength of materials used in the construction of the dies. Works closely with shop personnel to discuss any problems that may have arisen in the use of the dies and makes changes in the drawings to correct the difficulties.

Workers on this job must be familiar with forging and stamping practices and with the properties and characteristics of metals and metal alloys; must be able to determine the type of dies needed to produce stampings and forgings economically, to prepare detailed drawings, and to solve manufacturing problems. Usually requires two years of technical training and two years of practical experience.

SECTION IV

TRAINING REQUIREMENTS

When the field of work for which training is to be provided has been determined and the occupations in this cluster of jobs have been analyzed, the curricula and individual courses of study required to prepare students to perform the job duties may be prepared.

The job descriptions contained in Section III of this document, augmented by the individual job analyses made by the State, will provide much of the data needed for this purpose. The first paragraph in each job description describes the work performed, i. e., what the worker does and how and why he does it. The last paragraph covers performance requirements and provides information about the skills, knowledges, and abilities required of the worker in performing the job duties.

Form "B" illustrates a method for recording the skills and knowledges required for each of the jobs in the major grouping. The overall heading "Mechanical Drafting and Design Technology" is the field of work. Under this heading are the industries in which the individual jobs are usually found.

The first column lists the subject matter areas generally recognized as basic in a training program for this field of work. It is possible that other subject matter areas may have to be added and that other occupations may be found which belong in this cluster of related jobs.

The other columns list the jobs for which job descriptions have been included in Section III. If the job descriptions indicate that knowledge or skill in a certain area is essential, the letter "E" should be entered. If it is not absolutely essential but advisable for a worker to receive instruction in a specific area, the letter "A" is entered. The following example illustrates how the data in a job description can be used:

The work performed section of the job description covering Design Draftsman, Rocket Engine shows that the worker requires knowledge of physics, thermodynamics, hydraulics and the behavior

characteristics of liquid and solid fuels to determine engine dimensions; that he must consider such factors as effect of extreme temperatures on metals, the relationship of electrical instrumentation to other equipment; and that he uses a slide rule in making mathematical calculations. From this information the letter "E" would be entered for thermodynamics, fluid dynamics and hydraulics, strength of materials, physical metallurgy, slide rule, heat physics,and instrumentation.

The performance requirements section states specifically that instruction is required in algebra; trigonometry; plane, solid, and analytic geometry; mechanical drawing; machine design; and machine shop practices. It is, therefore, evident that an "E" would be entered opposite each of the applicable subject matter areas. This section also indicates that experience in rocketry is required in order to perform successfully on this job.

The nature of the work and the industry in which the job is found would suggest to an experienced analyst that aerodynamics, mechanics, and the theories of noise and vibration would be helpful to the worker on this job. In most cases, the letter "A" would be entered opposite each of these subject matter areas until the matter could be investigated further. In some cases, industry may supply training in these areas and in others it may not be advisable for the school to set up special courses in these areas because of limited demand for such skills in the employment market.

The completed chart (Form "B") serves the following purposes:

1. It suggests a curriculum for the field of work.

2. It indicates the subject matter areas required for training students for this field of work.

3. It identifies those subject matter areas which are common to most of the jobs in the cluster.

The techniques described in this publication together with this chart form a sound basis for organizing a training program which will meet specific technician training needs.

FORM B. - TRAINING REQUIREMENTS ANALYSIS

MECHANICAL DRAFTING AND DESIGN TECHNOLOGY

Subject Matter Areas Required (Instruction must be given in the application of science and mathematics) Symbols: A- Advisable E- Essential	Aircraft & Missile Manufacturing							Engines and Turbines				Machine Tool Manufacturing									
	ANALYST, GAGE DESIGN and PLANNING	DESIGN DRAFTSMAN, ELECTROMECHANICAL	DESIGN DRAFTSMAN, HYDRAULIC LINKAGE	ENGINEERING DRAWINGS CHECKER	LOFTSMAN	TOOL DESIGNER	TOOL PROOFER	DESIGN DRAFTSMAN, RAM JET ENGINE	DESIGN DRAFTSMAN, ROCKET ENGINE	ENGINE DEVELOPMENT TECHNICIAN (Inf., comb.)	STEAM TURBINE DESIGN TECHNICIAN	DESIGN DRAFTSMAN, MACHINERY	LAYOUT MAN AND CHECKER	DESIGN CHECKER	DIE DESIGNER					
A. MATHEMATICS																				
Algebra	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E					
Trigonometry	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E					
Plane Geometry		E	E			E		E	E	E	E	E	E		E					
Solid Geometry		E	E			E		E	E		E	E	E		E					
Analytic Geometry		E	E			E		E	E		E	E	E	E	E					
Descriptive Geometry	E		E	E	E	E	E			E	E	E		E	E					
Calculus																				
Slide Rule		E	E			E		E	E		E	E			E					
B. PHYSICS																				
Noise & Vibration									E	E	E									
Nuclear																				
Solid State			E			E			A			E			E					
Mechanics	E	E	E	E		E	E	E	E	E	E	E		E	E					
Heat						E	E	E	E	E	E	E			E					
Sound																				
Light																				
Electricity & Magnetism		E	E							E	E	E								
Physical Electronics																				
Electrical Measurements & Insts.		A								E	E									
C. MECHANICAL TECHNOLOGY																				
Machine Design			E	E				E	E	E	E		E	E						
Tool & Gage Design	E		E			E	E							E	E					
Mechanical Drafting	E	E		E	E	E	E	E	E	E	E	E	E	E	E					
Thermodynamics								E	E		E	E	E							
Fluid Dynamics & Hydraulics			E						E											
Strength of Materials	E	E	E	E		E		E	E	E	E	E	E		E					
Physical Metallurgy		E	E			E		E	E		E	E			E					
Machine Shop Operations 1/	E	E	E	E	E	E	E	A	E	E	E	E	E	E	E					
Precision Measuring Instruments	E					E	E			E		E	E	E	E					
Aerodynamics				A	E			A	A			E	E	E	E					
Technical Writing	A						A				E			A						

1/ This should not be construed to mean skill in the operation of machine tools. It means familiarity with machine shop operations and practices.

ADDENDA

The job descriptions in Section III were developed from occupational analysis studies made by the author and others while he was associated with the Occupational Analysis Branch of the Bureau of Employment Security, U. S. Department of Labor, and from source data in the "Dictionary of Occupational Titles," "Vocational-Technical Training for Industrial Occupations, Bulletin No. 228," and similar publications.

The job relationship techniques described in Section II were adapted from Section VI of the "Reference Manual for In-Plant Manpower Planning," which was prepared by, and under direction of, the author. A more detailed description of these materials and their sources are given below:

"Dictionary of Occupational Titles," Volume I, Definitions of Titles. Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Government Printing Office, March 1949, 1518 pp. (For sale by the Superintendent of Documents, Washington 25. $3.50.)

It contains definitions of the various jobs found in the American economy arranged alphabetically according to job titles. There are 22,028 definitions which are known by 40,023 titles.

"Dictionary of Occupational Titles," Volume II, Occupational Classification and Industry Index. Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Government Printing Office, March 1949, 743 pp. (For sale by the Superintendent of Documents, Washington 25. $2.00.)

This volume consists of five (5) sections: (1) the occupational classification section wherein the individual jobs are arranged according to their code numbers; (2) an index of the common commodities sold in retail and wholesale trade for classifying persons engaged in sales work; (3) a glossary which clarifies the various terms used in the job definition; (4) definitions of industrial designations to show the industry in which jobs defined in volume I are usually found; and (5) an alphabetical index of these industrial designations.

"Vocational-Technical Training for Industrial Occupations." Division of Vocational Education, U. S. Office of Education, Federal Security Agency. Washington: U. S. Government Printing Office, 1944, 307 pp. (Out of print) (Vocational Education Bulletin No. 228.)

This is a report of a consulting committee appointed by the U. S. Commissioner of Education setting forth its findings concerning the need for vocational-technical training, typical jobs for which such training is essential, job descriptions exemplifying various occupational fields, and other information pertaining to the nature of the need for vocational-technical training, including subject-matter requirements.

"A Guide to the Engineering Professions in the Aviation Industries." New York: Institute of the Aeronautical Science, 2 East 64th Street, January 1954, 64 pp.

This guide discusses the engineering shortage in general and describes what the aeronautical engineer is and what he does. It provides brief job descriptions for engineering and technician jobs and gives a list of engineering colleges and technical institutes which train students for work in aircraft manufacturing establishments.

"Reference Manual for In-Plant Manpower Planning." Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Government Printing Office, April 1951, 53 pp. (For sale by the Superintendent of Documents, Washington 25. 45 cents.)

The purpose of this manual is to provide employers with practical methods for use in manpower planning. It includes instructions and suggestions for: (1) preparing a job inventory, (2) converting plant job titles to a standard classification system, (3) a method for inventorying work-force skills, (4) a method for filling vacancies by in-plant transfer of workers, and (5) a method for determining the relationship between jobs.

"Training and Reference Manual for Job Analysis." United States Employment Service, U.S. Department of Labor. Washington: U.S. Government Printing Office, June 1944, 103 pp. (For sale by the Superintendent of Documents, Washington, D.C., 20402. 35 cents.)

This is a training and reference manual on job analysis which attempts to describe the best methods for obtaining accurate and discriminating information about jobs.

This addendum is intended to offer additional information regarding the purpose of this publication, and to clarify some of the terms used. It is important that all who use this document understand its purpose.

Clearly the Area Vocational Education programs established under Title VIII of the National Defense Education Act, P.L. 85-864, must meet these two specifications: They must involve scientific or technical knowledge, and they must be in fields necessary for the national defense. It is the purpose of Title VIII to provide such training to develop skilled manpower in recognized occupations to meet national defense needs. Persons trained in these programs are referred to by various job titles. Having met the requirements of the act, programs shall not be precluded because of the segment of industry concerned or the occupational titles or classifications under which persons may be employed.

There is no universally accepted definition of the word "technician." Industry usage is far from uniform and varies from identifying those giving direct support to scientists and engineers to highly specialized workers in limited fields of operations. Moreover, a specific job may be called that of a "technician" by one employer and assigned a different title or classification by another. Therefore, for purposes of this document, the meaning of the word "technician" shall be construed in accordance with Misc. 3561, revised September 1959: ". . . the word "technician" whether used as a noun or an adjective, whether singular or plural, will have reference to the scope of training and work capability rather than to employment classification as such."

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